Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 24 (2015) 47 – 55

Procedia Environmental Sciences

The 1st International Symposium on LAPAN-IPB Satellite for Food Security and Environmental Monitoring

Numerical classification, Subak zoning and land transfer function rice field in the Province of Bali based on Remote Sensing and GIS

Indayati Lanya*, N. Netera Subadiyasa, Ketut Sardiana, Gst. Putu Ratna Adi

Study Program of Agroecotechnology, Faculty of Agriculture, Udayana University

Abstract

Several regulations at the province as well as administrative districts level regarding on the zonation of Subak, are to protect agricultural lands in the sustainable context. Such kinds of rules are included in: Law No. 41/2009, Government Regulation (GR) No.11/2010, GR No. 15/2010, GR No.1/2011, GR No.12/2012, GR No.25/2012, GR No.30/2012, and the Ministry of Agriculture's regulation No.07/Permentan/OT.140/2/2012.Moreover, about 4700 ha paddy fields converted into other uses during 3 years (3 ha/day), especially in the wetland area, have been included in the Spatial Planning. In this study, several types of satellite images were used; Quickbird, Aster, Landsat 8, and Globe 2012-2013, in order to map the land use and land cover change from 2002to 2013. Some thematic maps, such as: watersheds boundary, land use, irrigation, topographic, rainfall, regional spatial planning, land suitability, land productivity and road network, are used as the spatial databases, variable parameters and adjusted weighting scores in the model analysis. The analysis employed those thematic maps and numerical classification of Subak zonation through overlaid and reselects procedures in ArcGIS. As the category thresholds, numerical classification with the total value greater than 125, the Subak zone needs to be protected, the value between of 100-125, it will be designated as the Subak buffer zone, and the values less than 100, it can be converted into other uses. As the results, there are about 53% (43,021.42 ha) of rice field in 2013 should be conserved for in the next 40 years; designated as the buffer zone of Subak 40,31% (38,398.38 ha), and the area can be converted to other uses about 14.26 % (13,542.14 ha).

Selection and peer-review under responsibility of the LISAT-FSEM Symposium Committee

*Keywords:*numerical classification; Subak zoning; protected; buffer; converted

* Corresponding author. Tel.: +62-361- 421-573.
E-mail address: indahnet@yahoo.co.id.

Selection and peer-review under responsibility of the LISAT-FSEM Symposium Committee
doi:10.1016/j.proenv.2015.03.008

1. Introduction

Development of tourisms in Bali has increased the conversion of paddy fields to non-agricultural lands in recent years, either as residential areas or other developments to support tourism accommodations. Conversion of wetland is the most evident in the tourist areas and its surrounding areas where it gives an access to the tourist attractions or others. The existence of publicly accessible roads was followed by the increasing of settlements, trading and other services. The phenomena occur is related to the availability of land in Bali, and it located mainly in the wetland areas.

Rice field in Bali is incorporated as the Subak system. It is not only an agricultural land resource, but contains of its environmental functions, social and agrarian culture, which is very noble in agricultural country. Subak system is agreed to be a property of the indigenous people of Bali; nationally recognized, and a world cultural heritage [1]. Consequently, the Subak needs to be protected, preserved and enhanced, and revitalized in order to remain their functions. Conflicts of interest in the use of water resources, especially for the needs of households, hotels, restaurants and other tourism industry, have an impact on the lack of irrigation water supply. Moreover, it can be affect to decrease the food supply.

According to the problem above, the Regional Government of Bali, either provincial or district level is required, due to laws coordination among Government Regulations and Rule of Governor/Mayor, which related to the monitoring of land use change and land protection. Spatial analysis of physical and environmental conditions in Subak is very important to determine where is the Subak area needs to be protected, as a buffering area or limited conversion, and the area can be converted.

Developing Laws or Regulations region governor, has been mandated by the Act, the Government Regulation (GR) and the Regulation of the Minister of Agriculture (Permentan).UU41 of 2009 [2] on the Protection of Agricultural Land Sustainable (LP2B); UUNo.26/2007on Spatial Planning [3], UU26/2009on National Spatial Planning [4], GR 11/2010 [5] on Control and Utilization of Abandoned Land, GR 15/2010 [6] on the Implementation of Spatial Planning, Regulation No. 1/2011 [7] on the Establishment and Transfer Function LP2B, GR 12/2012 on the protection of incentives and disincentives LP2B, GR 25/2012 on LP2B Information System, Government Regulation No. 30/2012 on the Protection LP2B Financing, Regulation 16/2009 on Spatial Planning Bali, Minister of Agriculture and Regulation 07/Permentan/OT.140/2/2012 about Technical Guidelines Criteria and Requirements Zone, Land and Land Reserves P2B. Local Government in Indonesia are generally reluctant to make LP2B Protection. In fact, none of local government in Bali has a Regional Regulation of Land Protection.

Indeed, a research to determine the criterion of classification and mapping of paddy fields in Bali is required. It is also related to the establishment of Subak zonation as the LP2B (Subak-protected / preserved, Subak buffer (limited conversion), and can be converted) in accordance with the requirements contained in the Act and Regulation. The Subak zonation mapping is part of a research strategy of the transfer function determination and control of agricultural land in anticipation the negative impact of tourist in Bali.

The purpose of our study are: 1) to monitor the dynamics use in paddy fields, 2) to explore several thematic maps as parameters and variables in a numerical classification, (2) to develop a Subak zonation by the numerical classification based on Remote Sensing and GIS technique, (3) to propose a management category of Subak in each zone area, as a sustainable and protected lands, buffer zone, and limited conversion.

2. Materials and Methods

Materials used in this study consisted of some thematic maps; they are: topographic maps [8] for analysis: watershed, high places, relief distance from the city center, and irrigation canals; regional spatial planning (RTRW), land suitability map, rainfall map, and map of rice production (Fig. 1). Satellite imageries used in the study are: Aster image (October 2013), Landsat 8 (2014) and a digital image of the Globe in 2012 and 2013.Such satellite datasets is used to determine a land use map. Additionally, we used secondary datasets; statistics of Bali [9] and agricultural datasets [10]. Moreover, we performed a specific set of computers with Arcmap10.1 (ArcGIS), which is used for digitizing and analysis such thematic maps.

Research location encompasses the island of Bali, especially paddy fields incorporated within Subak system. The characteristic of the land is largely dominated by the volcanic landform. The shape of area is dominated by area with high slope/elevation, hilly and mountainous. Rainfall rate is between 1000 to 2500 mm per year [11]. All area of

Subak in Bali is a wetland with some agricultural crops and has managed the soil and water by the development of bench terraces and irrigation system since the 7th century.

As the methods, analyzing and data processing are following several steps; 1) literature reviews, 2) interpretation of satellite imagery, 3) field survey (ground survey), (4) Subak zonation analysis: weighting and scoring various zoning variable parameters, 5) digital mapping thematic maps GIS-based, 6) mapping of Subak LP2B region through numerical analysis of thematic maps based on GIS (overlaid method, intersect and query analysis), 7) preparation of criteria of the wetland classification/palemahan subak (sustainable, buffer and can be converted).

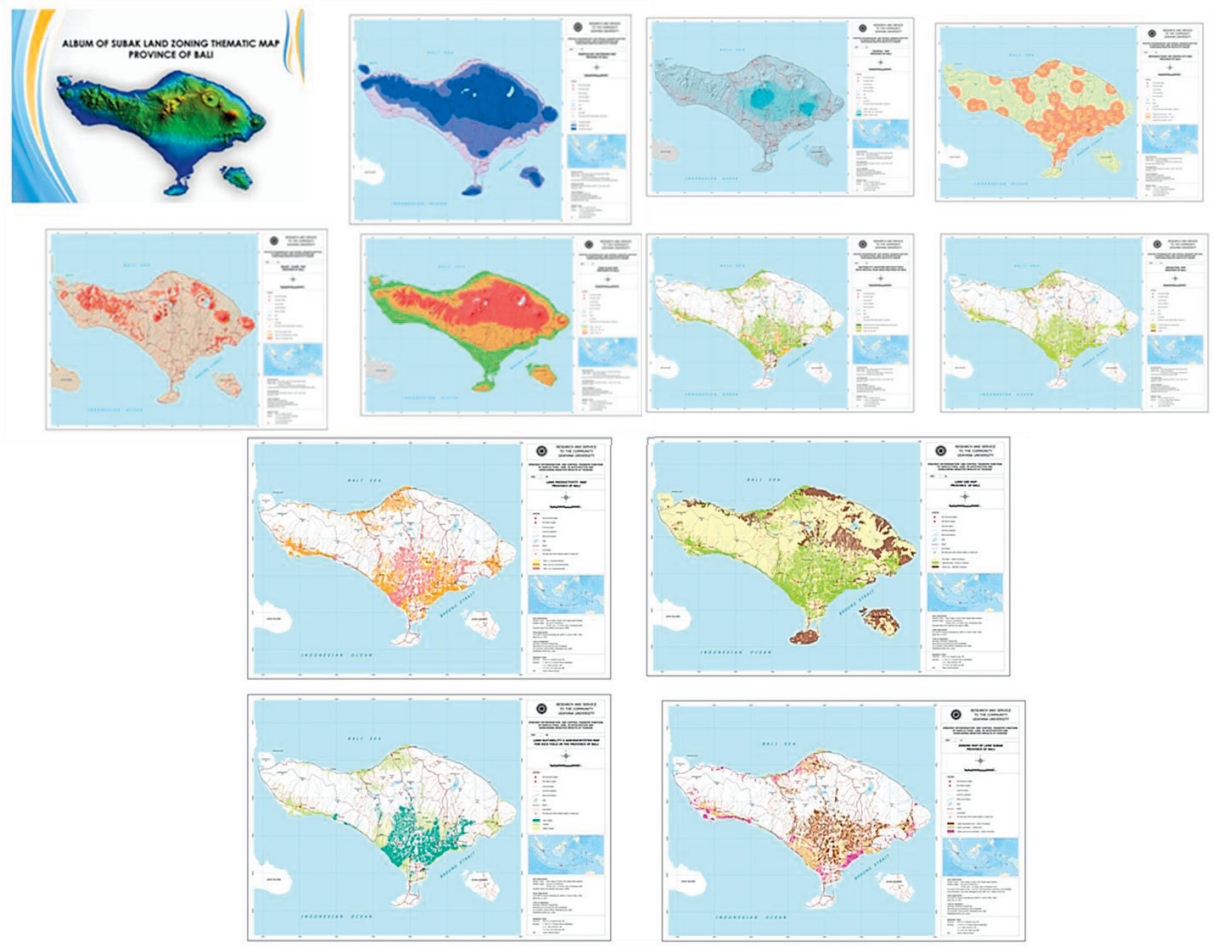

Fig 1. Album of thematic map, land zoning Subak, based on numerical classification

3. Results and Discussion

All A review of the literature of Act 41 of 2009 PLP2B Region, in Article 9 only contains land suitability, availability of infrastructure, land use, the technical potential of the land, and the unity of landscape or area for the entire territory of the province of Bali. In the article has not explained in more detail the physical condition of the area and the environment whatever is needed. In the region mapping PLP2B and sustainable supply of agricultural land is also based on the Act, namely: (1) soil fertility and land suitability of agro-ecosystem, (2) function Agroclimatology, hydrology, and ecosystems, (3) socio-cultural and local wisdom, (4) population growth and consumption needs of the population in the district and provincial level (5) productivity growth, (6) the need and availability of agricultural land, (7) land use, the technical potential of the land, (8) the extent of the unity of

landscape, (9) the availability of infrastructure, and the availability of facilities and infrastructure, (10) the development of science and technology, and (11) meetings of farmers, to eleven of these factors cannot be fully quantified and mapped, for that is used as the data and information supporting the usefulness of the results of the level of classification criteria PLP2B.

The change analysis of satellite images; Quick Bird in 2002, Aster imagery in 2013, and Landsat 8 in 2013, results the area changed in Bali's land uses as presented in Table 1 and in each district are presented in Table 2. Based on Table 1 shows that in 2002 extensive wetland 108,336.9942 Ha, turned into a moor area of 3,530,3569 ha and 24,839.4552 ha into other uses, so the rice area in 2013 only 79,967.1821 Ha. Moreover, statistics data of rice area is 81.165 ha [9].

Assumptions that rice area statistics are correct, then the results of the analysis of satellite imagery to obtain 98.53% accuracy rate, (79.967,18 Ha versus 81.165 Ha). According to Table 2, was obtained that the highest land conversion in Tabanan reached 6,197,40 ha, followed by the Denpasar city 3,667,45 ha, followed by Badung and Gianyar regency 1,431,72 2,888,30 ha. In other words, Sarbagita region experienced over the land area of 14,184,87 hectares over a period of 11 years (1,289,53 ha/ year), higher than the average of Bali 1000 ha/year [9].

Table 1. Land use changes of Bali Province 2002 to 2013

	District / Land	Year 2013			
	Use	Rice field (Ha)	Upland (Ha)	Other use (Ha)	Amount (Ha)
Year 2002	Bali Province				
	Rice field	79,967.1821	3,530.3569	24,839.4552	108,336.9942
	Upland		77,891.8144		77,891.8144
	Other use			375,150.1185	375,150.1185
	Total	79,967.1821	81,422.1713	399,989.5737	561,378.9371

The results of population census in Bali in 2010 as many as 5,908,757 people [12] or nearly 6 million people. While in 2010 had experienced the deficit, if only 1 x harvest and a slight surplus when the harvest index 1.5 times (based on paddy land area, rice production, and food needs). Bali's population is projected to reach 10,258,760 inhabitants in 2050. This means that it takes food doubled from 2010. Based on BPS data, the result of extensive analysis of of paddy fields, productivity, the rate of land conversion, and the population growth rate of Bali, there will be food crisis in 2040 as seen in Fig. 2.

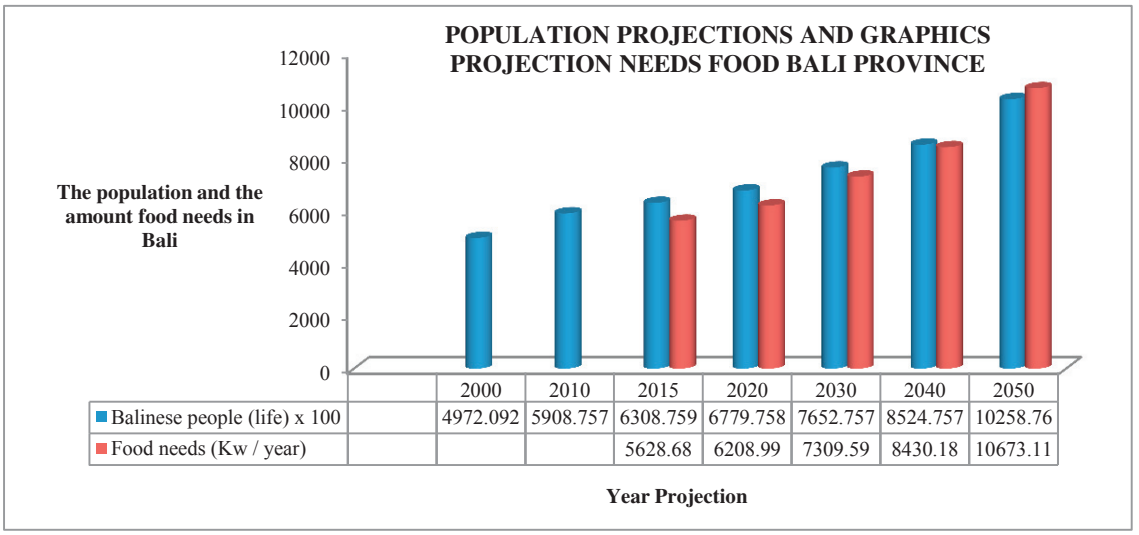

Fig 2. Projected population of Bali Province in 2015-2050 and food needs

Ten parameters zone classification and mapping of areas Subak include: (1) the position or location of Subak in the watershed (DAS) and or the upper reaches of the district / city, (2) land use, (3) a source of irrigation water, (4) conformity with the Spatial location of rice fields, (5) rainfall, (6) form the area and or relief or slope origin, (7) Cleaner place, (8) the suitability of land agro-ecosystem, (9) the productivity of land, and (10) the distance from settlements and urban centers. Ten parameters mentioned above, should be weighted and scoring for quantitatively assessed and classified according to the role of ecological functions and conservation of agricultural resources by taking into account the negative impact. Highest weight indicates the effect of multi-functional agriculture. Smaller weights with lower its role in environmental sustainability, Weights each scoring factor conducted in accordance with the level of the positive impact of multi-functional agriculture and environmental degradation, are presented in Table 3.

Maps of land use on the analysis of satellite imagery, watershed maps is obtained from RBI map and Quick Bird image interpretation which has been digitized and processed through ArcMap. Similarly, the maps: distance from the city center, altitude, irrigation with reference RBI maps, spatial maps, maps of the data BPN and irrigation PU were subsequently analyzed using GIS. GIS process is the analysis of maps, both digital thematic maps used as a parameter that has been done weighting and scoring also map the results of the analysis. The results of the tenth overlay the maps. The next step intersect method and query analysis, area zoning map has been produced sustainably LP2B Subak sustainable form of land area, Subak buffer and subak that can be converted. Results Subak sustainable regional mapping / LP2B based remote sensing and GIS is presented in Figure 2. Based on Figure 2, the area of each zone are described below.

Protected areas, the total value of ≥ 125 of 10 parameters. Location of protected areas (Subak sustainable) generally found in the upstream and mid watershed, rainfall > 2500 m above sea level. Land suitability according to agro-ecosystem is very appropriate, wavy relief to hilly. Subaks in the Bali Provincial spatial planning and spatial regency/city as a protected area, and local protection automatically as Subak sustainable. Based on analysis of the 10 thematic maps, through the process of GIS, obtained 43,021.42 Ha protected area, required Harvest index = 2.0, to feed the next 20 years (1 x Long-term development plan).

The protected area is only enough food to 2030, assuming no going over the land in this region. Lack of irrigation water and conflicts of interest with clean water for household needs, and accommodation facilities, tourism infrastructure, perverse impact of reducing intensity of planting rice in Bali.

Based on the analysis overlay of the 10 thematic maps resulted Subak zoning map, which shows that, land converted located on the coast. Especially around the Ida Bagus Mantra road, Kuta-Kerobokan, Tabanan beach, in the coastal region of Jembrana, Buleleng, Klungkung and Karangasem.

Bali's population in 2050 is projected to ± 10.25876 million inhabitants, it takes food 1,384,932,600 kg of rice, supplied by 461,644.2 hectares of rice fields. Food supply in 2013 is already in deficit. Unless Tabanan are experiencing self-sufficiency, to the Tabanan Regency as rice granary Bali Province, which is able to provide up to 2 x Long Term Development Plan (40 years). For the entire rice field in Bali needs to be protected or preserved. However, the need for the development of land should also be present. Subak zonation mapping results that can be converted 13542.14 ha. The food deficit will continue to occur, triggered by the conversion of agricultural land, as a result of land-use conflicts of interest and use of irrigation water. Improved production technology innovation and conservation of water needed to maintain food sovereignty.

Table 2. Land use year 2002 and 2013 based on the results of analysis of satellite imagery

	No	District / Land Use	Year 2013 Rice field (Ha)	Upland (Ha)	Other use (Ha)	Total (Ha)
Year 2002		Badung Regency				
		Rice field	9,868.29	343.02	2,888.30	13,099.62
	1	Upland		9,036.97		9,036.97
		Others use			17,803.76	17,803.76
		Total	9,868.29	9,379.99	20,692.07	39,940.35
	2	Bangli Regency				
		Rice field	2,270.95	239.55	513.79	3,024.28
		Upland		11,357.33		11,357.33
		Others use			38,342.95	38,342.95
		Total	2,270.95	11,596.87	38,856.74	52,724.56

3	Buleleng Regency				
	Rice field	11,443.24	1,318.35	2,792.23	15,553.82
	Upland		16,305.80		16,305.80
	Others use			99,539.38	99,539.38
	Total	11,443.24	17,624.14	102,331.62	131,399.00
4	Denpasar City				
	Rice field	2,355.60		3,667.45	6,023.05
	Upland		96.30		96.30
	Others use			6,471.73	6,471.73
	Total	2,355.60	96.30	10,139.18	12,591.09
5	Gianyar Regency				
	Rice field	15,187.59	19.46	1,431.72	16,638.76
	Upland		2,431.97		2,431.97
	Others use			17,713.75	17,713.75
	Total	15,187.59	2,451.43	19,145.46	36,784.48
6	Jembrana Regency				
	Rice field	7,088.04	7.11	2,462.19	9,557.35
	Upland		989.07		989.07
	Others use			75,441.07	75,441.07
	Total	7,088.04	996.18	77,903.26	85,987.49
7	Karangasem Regency				
	Rice field	6,691.45	1.20	3,897.18	10,589.83
	Upland		22,677.51		22,677.51
	Others use			50,759.44	50,759.44
	Total	6,691.45	22,678.72	54,656.62	84,026.79
8	Klungkung Regency				
	Rice field	3,880.97	69.47	989.19	4,939.64
	Upland		13,080.28		13,080.28
	Others use			14,696.22	14,696.22
	Total	3,880.97	13,149.75	15,685.41	32,716.13
9	Tabanan Regency				
	Rice field	21,181.05	1,532.19	6,197.40	28,910.64
	Upland		1,916.59		1,916.59
	Others use			54,381.81	54,381.81
	Total	21,181.05	3,448.78	60,579.21	85,209.03
	Total Amount Bali Province	79,967.18	81,422.17	399,989.57	561,378.93

Table 3. Criteria weighting and scoring each parameter, for zoning subak/ irrigation rice, terraces in Bali

No	Parameters	valuation		
		weight	score	Value
1	2	3	4	5
1	Position or location of Subak, the water shed and the administrative unit :	10		
	• Upstream watershed/regency/city		3	30
	• Central		2	20
	• Downstream		1	10
	Value			60
2	Land use	9		
	• Rice field		3	27
	• Field/Up land		2	18
	• Use of other land		1	9
	Value			54
3	Irrigation	8		
	• Irrigation technicalities semi-technical		3	24
	• Irrigation simple		2	16
	• Rainfed		1	8
	Value			48
4	Rainfall	7		
	• >2500mm/yr	7	3	21
	• 2000 - 2500mm/yr		2	14
	• <2000 mm /yr		1	7
	Value			42
5	The shape of the area/relief and slope	6		
	• Hilly terrain/slope>40%		3	18

	• Wavys/curly/slope of25-40%			2	12
	• Flat upto ramp/slope<25%,			1	6
		Value			36
6	High Places		5		
	• >500 m from the sea level			3	15
	• 100-500 m from the sea level			2	10
	• <100 m from the sea level			1	5
		Value			30
7	The suitability of the location of the fields, with the Spatial Planning		4		
	• Protected areas and protected strategic			3	12
	• Cultivation area of agriculture			2	8
	• Cultivation areao f non-agricultural			1	4
		Value			24
8	Agroecosystem land suitability, for paddy rice		3		
	• Very suitable			3	9
	• Suitable			2	6
	• Marginal suitable			1	3
		Value			18
9	land productivity		2		
	• >6.5 ton/ha / harvest			3	6
	• 5 to 6. 5ton/ha/ harvest			2	4
	• <5 ton /ha/ harvest			1	2
		Value			12
10	Distance from downtown		1		
	• >5km			3	3
	• 2.5 to 5km			2	2
	• <2.5 km			1	1
		Value			6

Criteria: Subak sustainable : the total value of >125
Subak buffer : total value of100 - 125
Subak converted : the total value of<100

3.1. Land Management for Sustainable Subak

3.1.1. Subak Sustainable

Subak sustainable irrigated fields as a catchment area, and multifunctional agricultural. Proposed to be 'protected area' in the Provincial Spatial and governed by Regulations PLP2B to district. Land use is regulated in Law 41/2009, Spatial Regulation, Regulation PLP2B, ie only for rice farming is regulated through licensing based on technical considerations zoning. Land conversion in accordance with GR 1/2011 and zoning of land within Detailed Spatial Plan. Paddy field owners are given incentives by the government and local government, in the form of property tax waivers, ease of land administration, and the ease in obtaining agricultural inputs such as seeds, fertilizers, pesticides, bank credit, and marketing of products. the local regulation, or regulation Governor / Regent / Mayor.

3.1.2. Subak Limited Conversion/Buffer Zone

The total value of between 100-125 of the 10 parameters mentioned above, total area of 38,398.38 ha buffer Subak. Location Subak conversion is limited, there are around centers of government. Its existence is contained in the spatial plans Spatial district / city as a food crop cultivation area: agriculture (crops, horticulture, and plantation), can be a mixture of the farm, which is called integrated farming, and farming on-farm and off-farm. Paddy fields, located in this area needs to be given intensive, in the form of taxes and subsidies dried production facilities, and in violation of the sanctions imposed. Required Local regulations on the Protection of Agricultural Land Sustained as mandated by UU 41/2009 [2], or incorporated into spatial planning and regulation. Farming in this area can be cultivated one of horticultural crops in crop rotation patterns. This region can be allocated to tourism is limited by not changing the landscape, such as agroecotourism, no damage contour bench terrace, do not damage the irrigation channels. Transfer function only to increase the added value of use, and land use, so it needs permission restrictions over the function according to the GR 1 / 2011. Transfer function must conform to the Spatial and conditions set forth in the Act (UU) and related or government regulation.

Regarding to the analysis, Area of Subak with total value less than 100 (< 100) of 10 parameters indicates that 13542.14 ha of area can be converted. Subak area locations, which can be converted contained in Spatial non-agricultural cultivation area, only allowed in a radius of 1 km from the city center district, a radius of 500 m from the center of the capital district, and a radius of 100 m from the sides of the road as provincial / district. Land management, in accordance with the Spatial and zoning map land for food crops. Transfer function is implemented through the licensing of land-use change, based on technical considerations of land use planning and other regulations. For those who violate the sanctions imposed in accordance with Law, GR, and local regulations relating to the Protection of Agricultural Land Sustainability.

4. Conclusion and Recommendation

4.1. Conclusion

The results of the analysis of satellite imagery Quick Bird 2002, Citra Aster, and Landsat satellite imagery 8 in 2013, conversion rice field in Bali 28,369.81 ha, or 2579.07 ha / year. Rice field 108,336.99 Ha in 2002, turned into a upland 3,530.36 Ha, and become other uses 24,839.45 hectares rice field area only 79,967.18 ha in 2013.

The highest land conversion in Tabanan reached of 6,197,40 ha, followed by the city of Denpasar 3,667.45 Ha, Badung 2888.30 Ha, Gianyar 1,431.72 Ha. Sarbagita region (Denpasar, Badung, Gianyar and Tabanan) experienced over the land area of 14184.87 hectares, over a period of 11 years (1,289.53 ha / year), satellite image interpretation accuracy rate 98.53%.

Bali Province has experienced a food deficit in 2013. It should be protected throughout the land Subak, particularly those found in protected areas / Subak sustainable, and Subak buffer in the farm area in Spatial Bali

1. Numerical classification and mapping Subak zoning or zoning of agricultural land sustainable food (LP2B) based remote sensing and GIS, obtained ten parameters. Weighting and scoring of each parameter based on physical factors, the environment, the potential of the region, and the impact on the sustainability of agricultural land resources.
2. The total value obtained from the results of numerical classification for land Subak protected / preserved, buffer land, and land that can be converted Subak can change, according to the regional food balance conditions for a specified period.

Agricultural land that needs to be protected / preserved / Subak sustainable over the next 40 years an area of 43021.42 hectares. Numerical classification with a total value of more than 125 of the 10 parameters. Contained in the upstream and middle watershed, irrigation technical, compliance with the Spatial high, as protected areas and farm area, undulating to hilly relief, rainfall is more than 2500 mm / year. Suitability of potential land is very suitable to suitable, harvest index more than 2 times, production of more than 5 tonnes / ha, the distance from the city center more than 5 km.

Subak buffer/conversion is limited, the total value of between 100-125 of the 10 parameters, the extent of 38398.38 ha. Subak land is generally located in the central part of the watershed, semi-technical irrigation to simple irrigation, get rainfall between 2000 mm - 2500 mm per year, at an altitude of 100 -500 m from the sea level, on a farm area, relief ramps up choppy, production 2.5- 5 tonnes / ha, the distance from the city center 2.5 to 5 km.

Subak that can be converted with a total value of less than 100 of the 10 parameters, an area of 13542.14 hectares. Rice field in the area of non-agricultural cultivation, are in an area with radius less than 2.5 km from the city center, is there a height of less than 100 m from the sea level, and rainfall is less than 2000 mm/year, rainfed.

4.2. Recommendation

Numerical classification and mapping system zoning Subak / LP2B region is expected to be accommodated in the Minister Agriculture bout LP2B establishment of criteria, such as morphology watershed, relief, slope, high places, land suitability with the Spatial, and the distance from the city center as a supply of land for construction.

The existence of classification and mapping technology based PL2B physical conditions of agricultural land, and environmental sustainability, is expected to help the local authorities to draw up LP2B Academic Assessment, as mandated by UU 41/2007.

References

[1] UNESCO; 2011.
[2] Undang-undang No. 41 of 2009 on the Protection of Agricultural Land Sustainable.google,co,id /
[3] Undang-Undang No. 26 of 2007 on Spatial Planning, http: // www google, co, id /
[4] Regional Regulation No. 26 of 2009 on Spatial Planning area of Bali Province, http: // www google, co, id /
[5] Government Regulation No. 11 of 2010 on Control and Utilization of Abandoned Land, http: // www google, co, id /\
[6] Government Regulation No. 15 of 2010 on Spatial Pengelenggaraan, http://www google, co, id
[7] Government Regulation No. 1 of 2011 on the Establishment and Transfer Function Food Sustainable Agriculture land, http: // www google, co, id
[8] BAKOSURTANAL; 2002.
[9] Central Bureau of Statistics Bali Province . Bali by the Numbers 2013. Denpasar: Central Bureau of Statistics Bali Province; 2013.
[10] Department of Agriculture; 2013.
[11] Daryono; 2012.
[12] Central Bureau of Statistics Bali Province. The Results of the 2010 Population Census, Aggregate Data by District / City of Bali Province, Provincial Statistics Navel Body Bali. Denpasar: Central Bureau of Statistics Bali Province; 2010.